

METHOD AND APPARATUS FOR OPTICAL ELEMENT MANAGEMENT

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of optical communication systems, and more particularly to a method and apparatus for managing one or more optical elements.

BACKGROUND

Optical amplification systems are becoming increasingly complex. For example, the number of channels being amplified continues to increase as the spacing between adjacent wavelengths utilized decreases and new communication bands are implemented. Moreover, as the distance the optical signals traverse increases, the number of optical elements and spans of fiber in each optical link increases.

As the amplification systems increase in complexity, it becomes increasingly difficult to track and manage the specifics of how each element is provisioned and the operational characteristics of the elements.

OVERVIEW OF EXAMPLE EMBODIMENTS

5 The present invention recognizes a need for a method and apparatus operable to facilitate monitoring and/or management of the operation of one or more optical elements. Various implementations of the present invention reduce or eliminate at least some of the shortcomings of conventional element management approaches.

10 In one aspect of the invention, a method of managing one or more optical elements comprises storing in a memory, provisioning information describing at least one setting of an optical element and monitored information describing at least one operational characteristic of the optical element. At least a portion of the monitored
15 information is correlated with at least a portion of the provisioning information. The method further comprises maintaining in the memory, a correlation history comprising the provisioning information stored over time and the monitored information correlated to that
20 provisioning information.

25 In another aspect of the invention, a method of managing one or more optical elements comprises accessing a memory comprising monitored information describing at least one operational characteristic of an optical element measured at a plurality of time periods. The
30 memory further comprises provisioning information correlated with at least some of the monitored information. The provisioning information describes at least one setting of the optical element. The method also comprises retrieving provisioning information correlated with monitored information reflecting a desired operational characteristic of the optical

element. In addition, the method comprises applying at least a portion of the retrieved information to an application operable to monitor and/or modify the performance of the optical element based at least in part on the retrieved information.

In yet another aspect of the invention, a system operable to facilitate management of one or more optical elements comprises an element agent operable to receive provisioning information describing at least one setting of an optical element and monitoring information describing at least one operational characteristic of the optical element. At least a portion of the provisioning information is correlated with at least a portion of the monitored information. The system further comprises an element memory accessible to the element agent and operable to maintain a correlation history for the element, the correlation history comprising a plurality of correlated provisioning and monitored information measurements.

Depending on the specific features implemented, particular embodiments of the present invention may exhibit some, none, or all of the following technical advantages. For example, various embodiments of the invention facilitate maintaining a correlation history including provisioning information correlated with monitored information over a period of operation of an optical element, an optical link, or a plurality of optical links. The correlation history can facilitate various maintenance operations and/or efficiency enhancing functions with respect to the element's and/or link's operation.

For example, a graphical user interface (GUI) could display one or more sets of correlated provisioning information and monitored information to facilitate identification of trends in operation, to identify a malfunctioning component of the element, to facilitate optimization of operation, or various other utilities. As another example, the correlation history could facilitate "before and after" comparisons to assess the impact of a change in provisioning to the operation of the element and/or the link.

As still another example, the correlation history could facilitate identification of improper or inefficient provisioning settings in a particular element or link. As a related example, the correlation history could facilitate reversion provisioning. For example, the correlation history could store a set of provisioning information, which is known based, for example, on past experience to yield desired results. By indexing the correlation history using a portion of the provisioning information and one or more desired operational

characteristics, the remaining provisioning information associated with the desired operating characteristics can be recalled and applied to the element and/or the link.

5 These are just a few examples of advantageous uses
of a correlation history in an optical amplification
system. Various other uses of this information fall
within the spirit and scope of this invention. Other
technical advantages are readily apparent to one of skill
in the art from the attached figures, description, and
10 claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and for further features and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a block diagram showing an exemplary optical communication system constructed according to the teachings of the present invention;

FIGURE 2 is a block diagram showing one example of an amplification span constructed according to the teachings of the present invention;

FIGURE 3 is a block diagram of one example of a correlation history associated with a particular optical element constructed according to the teachings of the present invention;

FIGURE 4 is a block diagram of a link management system constructed according to the teachings of the present invention;

FIGURE 5 is a block diagram showing one example of a multiple link management system constructed according to the teachings of the present invention; and

FIGURE 6 is a flow chart illustrating one example of a method of managing one or more optical elements according to the teachings of the present invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

FIGURE 1 is a block diagram showing an exemplary optical communication system 10 operable to facilitate communication of one or more optical signals and to track and/or manage the operation of one or more optical elements in system 10. Optical amplifiers, optical add/drop multiplexers, cross connects, input terminals including optical transmitters, and output terminals including optical receivers provide just a few examples of optical elements that can be monitored and/or managed using system 10.

In this example, system 10 includes an input terminal 11. In the illustrated embodiment, input terminal 11 includes a transmitter bank 12 operable to generate a plurality of wavelength signals (or channels) 16a-16n. Each wavelength signal 16a-16n comprises a wavelength or range of wavelengths of light substantially different from wavelengths carried by other signals 16.

Transmitter bank 12 may include, for example, one or more optical transmitters operable to generate alone or in combination a plurality of wavelength signals 16. In one embodiment, each one of the plurality of transmitters is operable to generate one optical signal having at least one wavelength that is distinct from wavelengths generated by other transmitters 12. Alternatively, a single transmitter 12 operable to generate a plurality of wavelength signals could be implemented.

In the illustrated embodiment, input terminal 11 also includes a combiner 14 operable to receive multiple signal wavelengths 16a-16n and to combine those signal wavelengths into a single multiple wavelength signal 16. As one particular example, combiner 14 could comprise a

wavelength division multiplexer (WDM). The term wavelength division multiplexer as used herein may include wavelength division multiplexers or dense wavelength division multiplexers.

5 In this particular example, input terminal 11 further includes a booster amplifier 18 operable to receive and amplify wavelengths of signal 16a in preparation for communication over a communication medium 20. Although this example illustrates input terminal 11
10 as including each of transmitter bank 12, combiner 14, and booster amplifier 18, one or more of those elements could reside externally to input terminal 11.

System 10 communicates optical signal 16 over an optical communication medium 20. Communication medium 20
15 can comprise a plurality of spans 20a-20n of fiber, each separated by an optical element. As used in this document, the term "span" refers to an optical medium coupled to one or more optical elements. As particular examples, fiber spans 20 could comprise standard single
20 mode fiber (SMF), dispersion-shifted fiber (DSF), non-zero dispersion-shifted fiber (NZDSF), or other fiber type or combinations of fiber types.

Two or more spans of medium 20 can collectively form an optical link. As used herein, the term "optical link"
25 refers to a plurality of optical spans coupled to one or more optical elements. In the illustrated example, system 10 includes one link 25. System 10 could alternatively include any number of additional links.

In this example, system 10 also includes one or more
30 in-line amplifiers 22a-22m. In-line amplifiers 22 reside between fiber spans 20 and operate to amplify signal 16 as it traverses fiber 20.

In this example, system 10 includes one or more add/drop multiplexers, switches, and/or routers 15 coupled to communication medium 20 and operable to direct signals to and from optical link 25 for combination with signals to and from other optical links. Element 15 may be coupled to an amplifier or may itself be capable of amplifying optical signals received.

System 10 can also include an output terminal 13 operable to receive signals from communication link 20 and to facilitate, for example, conversion of the optical signals to an electrical format. In this example, output terminal 13 includes a preamplifier 24 operable to receive signal 16 from a final fiber span 20n and to amplify signal 16 prior to passing that signal to a separator 26. Separator 26 may comprise, for example, a wavelength division demultiplexer (WDM). Separator 26 operates to separate individual wavelength signals 16a-16n from multiple wavelength signal 16. Separator 26 can communicate individual signal wavelengths or ranges of wavelengths 16a-16n to a bank of receivers 28 and/or other optical communication paths. Although this example illustrates output terminal 13 as including each of preamplifier 24, separator 26, and receivers 28, one or more of those elements could reside externally to output terminal 13.

Amplifiers within system 10 could each comprise, for example, a rare earth doped amplifier such as an erbium doped or thulium doped amplifier, a Raman amplifier, a semiconductor amplifier, or a hybrid or combination of these or other amplifier types.

At least one optical element in system 10 comprises or communicates with a management system 30 operable to

track and/or manage the performance of that element or of the optical link containing that element. Management system 30 operates to store provisioning information describing at least one setting of the element and to store monitored information describing at least one operational characteristic of the element. Management system 30 correlates at least some of the provisioning information with at least some of the monitored information and maintains a correlation history useful in a variety of applications.

FIGURE 2 is a block diagram showing one example of an amplification span 100 including an optical element 110 and an element manager 130 operable to track and/or manage the performance of element 110. In this particular example, element 110 comprises an input terminal including a plurality of optical transmitters and a booster amplifier. Although this example describes implementing element manager in combination with an input terminal, element manager 130 could alternatively be used to track and/or manage any other type of optical element in system 10, such as an in-line or other type of amplifier, an output terminal, an add/drop multiplexer, a cross connect, or a router, to name a few.

The booster amplifier of element 110 may comprise any type of amplifier including, for example, a rare-earth doped amplifier, a distributed Raman amplifier, a discrete Raman amplifier, a semiconductor amplifier, or a combination of these or other types of amplifiers. Element 110 couples to optical span 120a, which might comprise, for example, a span of standard single mode fiber, dispersion-shifted fiber, non-zero

dispersion-shifted fiber, or other fiber type or combinations of fiber types.

Element manager 130 includes an element agent 132 operable to receive provisioning information 140 and monitoring information 142. Provisioning information 140 comprises information describing at least one setting of element 110. For example, provisioning information 140 could comprise information relating to the gain of the preamplifier in element 110, a laser drive current associated with one or more of the transmitters or the preamplifier in element 110, a pre-emphasis level associated with element 110, or a number of channels being processed by element 110, to name a few. Other optical elements may store these or various other items of provisioning information, depending on the particular application of the optical element.

Monitored information 142 comprises information describing at least one operational characteristic of element 110. Monitored information 142 can be obtained at various locations along amplification span 100. For example, monitored information 142 may be collected from an input to element 110 or from an output of element 110. Examples of monitored information 142 include input power, output power, mid-stage power, gain tilt, signal-to-noise ratio, back reflected power, total transmitted power, per channel transmitted power, total received power, or per channel received power, pump laser power, pump laser drive current, thermal electrical cooler settings, thermal electrical cooler drive currents, to name a few. Of course, the particular monitored information collected can vary depending on the function of the element being monitored. Moreover, other

or additional operational characteristics could be monitored without departing from the scope of the invention.

5 In one particular embodiment, element agent 132 operates to query element 110 to obtain provisioning information 140 and/or monitored information 142. Rather than recording provisioning information 140 and/or monitored information 142 only when provisioning characteristics are changed, element agent 132 can
10 periodically, on a random basis, or on command query element 110 to retrieve provisioning information 140 and/or monitored information 142.

Regardless of how or when element agent 132 receives provisioning information 140 and monitored information
15 142, element agent 132 stores the information received in a memory 134. Memory 134 may comprise, for example, any hardware, firmware, software, or combination thereof operable to store and facilitate retrieval of information. Memory 134 can comprise any of a variety of
20 data structures, arrangements, or compilations operable to store and facilitate retrieval of various information. This may include, for example, the use of a dynamic random access memory (DRAM), a static random access memory (SRAM), or any other suitable volatile or
25 non-volatile storage and retrieval device or a combination of devices. Although, in this embodiment, memory 134 is shown as residing within element manager 130, all or a portion of memory 134 could reside remotely from and accessible to element agent 132.

30 In the illustrated embodiment, memory 134 includes a correlation history 136. Correlation history 136 may comprise, for example, a memory operable to store

provisioning information 140 and monitored information 142, where at least a portion of monitored information 142 is correlated with at least a portion of provisioning information 140. Correlation history 136 can include a plurality of sets of correlated provisioning information 140 and monitored information 142 stored over a period of time of operation of element 110.

Memory 134 is accessible to one or more applications 150 operable to monitor, display, report on, analyze, and/or modify the performance of element 110 based at least in part on information retrieved from memory 134.

In operation, element agent 132 receives provisioning information 140 and monitored information 142 correlated with at least a portion of provisioning information 140. In a particular embodiment, element agent 132 may query element 110 to retrieve this information. Element agent 132 may receive provisioning information 140 and correlated monitored information 142 at various times during operation of element 110.

Element agent 132 stores provisioning information 140 and correlated monitored information 142 in memory 134. In a particular embodiment, element agent 132 stores provisioning information 140 and correlated monitored information 142 associated with a particular time period in a record stored in correlation history 136. Over time, element agent 132 may store a plurality of records containing provisioning information 140 and correlated monitored information 142 associated with particular time periods. In a particular embodiment, these records can collectively form correlation history 136.

One or more applications 150 access information in memory 134 to track and/or manage the performance of element 110. As one particular example, application 150 may comprise a graphical user interface (GUI) operable to display one or more sets of correlated provisioning information 140 and monitored information 142. This may facilitate, for example, inspection of provisioned and operational characteristics of element 110 to identify trends in operation, to identify a malfunctioning component of element 110, to facilitate optimization of operation, or various other utilities.

As another example, application 150 could comprise a benchmarking application operable to facilitate "before and after" comparisons to assess the impact of a change in provisioning to the operation of element 110.

As still another example, application 150 could comprise a trouble shooting application operable to identify improper or inefficient provisioning settings in element 110. For example, trouble shooting application 150 could index correlation history 136 using monitored information representing desired operational characteristics to identify provisioning information previously correlated with those characteristics. This provisioning information could represent a provisioning state known to produce desirable operational characteristics. Application 150 can then compare the retrieved provisioning information 140 with the current element settings to facilitate identification of problems with and/or modification of the provisioning of element 110 so that its operation can more closely approximate the desired state of operation.

As a related example, application 150 could facilitate reversion provisioning. For example, correlation history 136 may store a set of provisioning information 140, which is known based, for example, on past experience to yield desired results. By indexing correlation history 136 using a portion of the provisioning information and one or more desired operational characteristics, the remaining provisioning information associated with the desired operating characteristics can be recalled.

As a particular example, one set of provisioning information 140 and monitored information 142 may identify pump power levels, pre-emphasis levels, and/or amplifier gain levels associated with a particular number of channels and particular operational characteristics. As the number of channels processed by element 110 changes over time, provisioning information 140 associated with the element may also change. When the number of channels returns to its original state, a reversion provisioning application 150 can facilitate automatically reverting to the set of provisioning information previously used by element 110 when dealing with that particular number of channels. This can eliminate guesswork and inefficiency associated with trying to recreate that set of provisioning information based on a trial and error approach. By, for example, searching correlation history 136 for provisioning information 140 containing a desired number of channels, and possibly correlated with a desired output characteristic, reversion provisioning application 150 can apply all or a part of the retrieved provisioning

information 140 to revert element 110 to previously approved element settings.

5 These are just a few examples of advantageous uses of correlation history 136 in system 100. Various other uses of this information fall within the spirit and scope of this invention.

10 FIGURE 3 is a block diagram of one example of a correlation history 236 associated with a particular optical element, for example, optical element 110 described with respect to FIGURE 2. In this example, correlation history 236 includes a plurality of records 210a-210n. Each record includes provisioning information 240 and monitored information 242 associated with element 110 at a particular time 250.

15 Provisioning information 250 may include, for example, information regarding channel pre-emphasis used in element 110 as well as and the number of channels processed by element 110. Other provisioning information could be stored without departing from the scope of the invention. Monitored information 242 could include, for
20 example, input power, mid-stage power, output power, gain tilt, optical-signal-to-noise-ratio, back reflected power, or any other operational characteristics associated with element 110.

25 In a particular embodiment, any individual piece of provisioning information 240 can be used as an index to retrieve any piece of monitored information 242 residing in the same record. Likewise, items of monitored information 242 can be used as an index to retrieve any
30 item of provisioning information 240 from the same record 210. In addition, any piece of provisioning or monitored information could be used to access all or a portion of

any other correlated information. Other arrangements and correlation schemes could be used without departing from the scope of the invention. The above-described correlation is intended as just one example.

5 FIGURE 4 is a block diagram of a link management system 300. Link management system 300 includes an optical link 320 comprising a plurality of spans 320a-320n. Each optical span comprises an optical fiber coupled to one or more optical elements 310. Each
10 element in system 300 has associated with it a local element manager 330. Local element managers 330 are similar in structure and function to element manager 130 described with respect to FIGURE 2. Each local element manager 330 includes an element agent 332 operable to
15 receive provisioning information 340 and monitored information 342 from its associated element 310. Element agents 332 store provisioning information 340 and monitored information 342 in their associated memories 334.

20 As in the embodiment shown in FIGURE 2, memories 334 may store correlation histories 336, which include provisioning information 340 correlated to monitored information 342. One or more element applications 350 may access memories 334 to track and/or modify
25 performance of individual elements 310 or combinations of elements 310.

30 In the illustrated embodiment, system 300 includes a link manager 360 operable to track and/or modify performance of one or more elements 310 and/or the entire optical link 320. In this example, link manager 360 includes a manager agent 362 operable to receive provisioning and monitored information from each of

elements 310. Manager agent 362 may receive this information, for example, through each element agent 332 querying elements 310, or may obtain information already queried or otherwise received from elements 310 and stored in element memories 334. Link manager 360 also includes one or more memories 364. Memory 364 stores information associated with each element 310 in optical link 320.

Link manager 360 may also receive information from adaptation module 370. Adaptation module 370 comprises hardware, software, and/or firmware operable to facilitate retrieval of provisioning and/or monitored information of various manufacturers' equipment. For example, equipment interfacing with adaptation module 370 may provide provisioning and/or monitored information in a format other than the format typically used by link manager 360. Adaptation module 370 operates to reformat the information received so that it can be assimilated and/or correlated with other information associated with optical link 320.

Link manager 360 may further include one or more applications 365 operable to track and/or manage operation of elements 310 and/or optical link 320 based at least in part on provisioning information and monitored information associated with those elements. Application 365 may obtain such information, for example, from records residing in manager memory 364. Application 365 may provide some or all of the functions of application 150 described with respect to FIGURE 2. In addition, application 365 may facilitate tracking and/or managing the operation of optical link 320.

For example, application 365 may facilitate identifying a malfunctioning component in one or more elements 310 by examining the operation of optical link 320. As a particular example, a pump driving one of an element including an amplifier may be weakening. Application 365 may compare various characteristics associated with elements in optical link 320 to identify the weakening amplifier pump. Application 365 may, for example, compare input powers to each amplifier and pump powers driving each amplifier to determine the location of a weakening pump.

In one case, application 365 may determine that a particular element 310b is receiving an appropriate power level input signal, but exhibiting a high drive current to its laser pump. This indicates that the driving source associated with element 310b is likely weakening. In another case, application 365 may determine that although element 310b has an abnormally high pump power, the input signal to element 310b is abnormally low. This could indicate, for example, a malfunction in the previous amplifier 310a in that span, or a fault in optical span 320b between elements 310a and 310b. System 300 facilitates pinpointing the location of a malfunction in an optical link by facilitate simultaneous analysis of characteristics associated with a number of elements 310 along optical link 320.

In this example, link manager 360 includes an interface 380, which facilitates an external application 390 accessing and retrieving information from manager memory 364. External application 390 may comprise a module remote from optical link 320, which is operable to access provisioning and monitored information associated

with link 320 and to facilitate tracking and/or management of elements 310 and/or optical link 320. Interface 380 could provide security features to protect correlation histories 364 from unauthorized access by external entities.

In this particular example's operation, link 320 receives optical signals at an element 310a comprising an amplifier, which amplifies the optical signals and communicates them toward the next element 310. Element agents 332 associated with each element 310 may periodically, on a random basis, or on command receive or retrieve provisioning and monitored information from one or more elements 310. Element agents 332 store the provisioning and correlated monitored information in correlation histories 336 of memories 334. Manager agent 362 on demand, on a periodic basis, or on a random basis, accesses and retrieves provisioning and correlated monitored information associated with each element 310 and stores that information in manager memory 364. Manager applications 365 and/or external applications 390 track and/or modify the operation of elements 310 and/or optical links 320 based at least in part on provisioning and monitored information associated with those amplifiers.

FIGURE 5 is a block diagram showing one example of a multiple link management system 400. Multiple link management system 400 includes a system manager 460 operable to track and/or manage one or more optical links in system 400. System manager 460 is similar in structure and function to link manager 360 shown in FIGURE 4, and has capabilities of managing numerous optical links 420a-420n.

System manager comprises a manager agent 462 operable to receive provisioning and monitored information from numerous elements in one or more optical links 420a-420n. Manager agent 462 can receive this information, for example, through each element agent 432 querying elements 410, or may obtain information already queried or otherwise received from elements 410 and stored in element memories 434. System manager 460 also includes one or more memories 464a-464n. Memories 464a-464n could be physically separate storage devices, or could comprise logically partitioned regions of one or more common memory devices. Each memory 464 stores information associated with each element 410 in its associated optical link 420.

System manager 460 may also receive information from adaptation module 470. Adaptation module 470 comprises hardware, software, and/or firmware operable to facilitate retrieval of provisioning and/or monitored information of various manufacturers' equipment. For example, equipment interfacing with adaptation module 470 may provide provisioning and/or monitored information in a format other than the format typically used by link manager 460. Adaptation module 470 operates to reformat the information received so that it can be assimilated and/or correlated with other information associated with optical link 420.

Link manager 460 may further include one or more element applications 465a-465n operable to track and/or manage operation of elements 410 and/or optical links 420 based at least in part on provisioning information and monitored information associated with those elements and/or links. Applications 465 may provide some or all

of the functions of application 150 described with respect to FIGURE 2. In addition, application 465 may facilitate tracking and/or managing the operation of optical links 420a-420n individually, or in combination with one another.

FIGURE 6 is a flow chart illustrating one example of a method 500 of managing one or more optical elements. To provide one particular example, method 500 will be described with primarily with respect to management system 100 shown in FIGURE 2. Other management systems managing different types of optical elements could implement method 500 without departing from the scope of the invention.

In this example, method 500 begins at step 510 where system 100 stores provisioning information 140 in element memory 134. System 100 can obtain provisioning information 140, for example, by using query module 133 to query element 110 on command, periodically, or on a random basis to obtain provision information 140. In a similar manner, system 100 stores monitored information 142 in memory 134. Element agent 132 could, for example, implement query module 133 to retrieve monitored information 142.

Element agent 132 maintains a correlation history 136 at step 530. Correlation history 136 comprises a plurality of correlated values of provisioning information 140 and monitored information 142. Correlation history 136 provides a historical view of the manner in which monitored information 142 varies as provisioning information 140 changes. In addition, correlation history 136 can show the way monitored

information 142 can change over time even though provisioning information 140 remains constant.

In this example, element agent 132 accesses memory 134 at step 540 to retrieve correlated provisioning and monitored information. Element agent 132 applies at least a portion of the retrieved correlated information to application 150 at step 550. As particular non-limiting examples, application 150 can operate to display correlated information to users, or may analyze this information to facilitate modifying the operation of element 110. For example, application 150 may retrieve provisioning information from correlation history 136 by indexing correlation history 136 with a known value of monitored information 142 corresponding to a desired state of operation. Application 150 can then compare the retrieved provisioning information with provisioning information currently associated with element 110 to determine changes that need to be made in the provisioning of element 110 to result in the desired state of operation.

As another example, application 150 could perform reversion provisioning. As one example of reversion provisioning, application 150 could index correlation history 136 using one portion of provisioning information 140 to obtain a full set of provisioning information associated with that portion and possibly also associated with a desired state of operation.

Although this example has been described with respect to managing a single element 110, method 500 can equally apply to management of multiple elements in a single optical link, or to managing multiple optical links. Systems shown in FIGURES 4 and 5 provide two

non-limiting examples of systems that could implement method 500.

Although the present invention has been described in several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformations, and modifications as fall within the spirit and scope of the appended claims.

5

10

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2